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ONTARIO

Ministry of the ENVIRONMENT

Hamilton Harbour Modelling Study

1972

HAMILTON HARBOUR MODELLING STUDY

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MINISTRY OF THE ENVIRONMENT
April 28, 1972

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PURPOSE

The aim of the study is to understand the water dynamics, chemical and biological processes of the harbour in sufficient detail that it is possible to predict what changes are likely to occur due to the proposed filling program and the changing industrial and municipal waste discharges to the harbour. The study will also assess the effects of various water management programs which would be implemented to improve water quality in the harbour.

The effect of the effluent from the ships' channel on the existing adjacent lakeshore water intakes will also be assessed.

INTRODUCTION

When considering the basic question of the implications on water quality of the proposed land reclamation projects in Hamilton Harbour, there are a number of inter-related factors which require concurrent consideration. The simple assumption of just increasing water chemistry parameters proportionally to the reduction in harbour volume cannot be supported unless the following factors are considered.

1. Some industrial land filling is for plant expansion resulting in changes in waste discharges to the harbour.

2. Future urban growth will result in changes in waste discharges to the harbour.

3. Water movement patterns and dispersion in the harbour are a function of the shoreline geometry, depths, water levels and winds.

4. Chemical dilution achieved through the ships' channel is periodic and a function of harbour concentrations and geometry.

5. Natural assimilative capacity of the harbour is not only a function of water volume, but also a function of exchange with lake water and loadings. Presently, nutrients are not a problem, as phosphates discharged to the harbour are converted to an insoluble form by existing iron discharges. If this balance is destroyed, algae growths may proliferate reducing dissolved oxygen levels which are already approaching annoxic conditions at various locations.

A comprehsnive study is required to develop models which can handle the variation of waste discharges and harbour geometry. While the presently proposed industrial land filling program will probably not significantly degrade existing water quality in the harbour, the expected changes in industrial and municipal waste discharges may cause problems. These two are obviously inter-related. It is also important to consider that further land filling will probably be proposed in the future with changes in waste discharges to the harbour.

The program proposed in the following sections embraces a concept of developing a means of predicting what effects evolving industrial and urban growth will have on the harbour in the future. The program produces a water management tool which can assess proposed methods of improving water quality i.e. induced circulation with the lake, destratification, changes in treatment facilities, etc. This program will also be co-ordinated with other relevant concurrent studies i.e. the Halton-Wentworth waterfront study by Acres Consulting Services Ltd. and Project Planning Associates Ltd.

PREVIOUS STUDIES

Numerous water quality surveys have been conducted in the harbour by various agencies commencing in detail in the early 1950's. The surveys reviewed are listed in the references. The principle findings of the reports can be summarized as follows:

1. The mean concentrations of many water quality parameters are increasing annually (Table 1) with the exception of bacteria counts which are decreasing. Of particular concern are the concentrations of ammonia (Table 1) and the annoxic conditions existing in portions of the harbour. Presently, the harbour water is significantly poorer in quality than lake water.

2. The concentrations of many water quality parameters are reasonably homogeneous in spatial distribution in the epilimnon although both seasonal and depth differences do exist (Table 3). Exceptions to the homogeneous mixture are the poorer quality areas along the industrial shoreline and the western end of the harbour and the better quality regions on the harbour side of the ships' channel and the north shore.

3. The annual surface runoff from the drainage area tributary to the harbour is approximately 40% of the harbour volume with the annual recirculating industrial discharge representing 240% of the harbour volume and non-recirculated discharge representing 35% of the harbour volume annually.

4. Measured wind set-ups in the harbour have been 0.32 m with similar differences of elevation of water surface existing between the ends of the ships' channel. These differences in elevation indicate strong periodic currents exist in the harbour and the ships' channel.

Water quality survey results in 1971 were different than other years as chlorides showed a large significant difference between the western and eastern end of the Bay. Increase in harbour ammonia concentrations (Figure 2) has not been reflected in the ammonia measurements at the raw water intake (Table 2) although the ammonia values at the water intake are higher than lake water farther offshore.

Process changes at Stelco and Dofasco have taken place which have had a significant effect on the discharge of ammonia and chlorides. However, the comprehensive waste control programs at both plants include facilities for the control of these items.

Ammonia is a by-product of the coke making operations and both companies have expanded coking facilities in recent years, Dofasco in 1967 and 1971 and Stelco in 1968. Dofasco installed equipment for the removal of ammonia in late 1971 and further improvements are expected within the next year. Stelco has negotiated for the acceptance of ammonia bearing wastes into the City of Hamilton sanitary sewerage system where the ammonia will be treated at the municipal sewage treatment plant. The diversion is expected to take place late in 1972.

The main effect on the discharge of chlorides was the conversion from sulphuric to hydrochloric acid in the pickle lines at both steel mills. Stelco changed to hydrochloric acid in stages in 1965, 1968 and 1970 and an acid regeneration plant has been in operation for several years. Dofasco switched to hydrochloric in 1967-68, 1971 and 1972 and the acid regeneration plant will be starting up in mid 1972. Acid regeneration eliminates the batch discharges of spent pickle liquor.

HARBOUR PROPERTIES REQUIRING DEFINITION

Information is lacking on the following:

1. The inflow and outflow properties of the ships' channel.
2. A more detailed understanding of time variations of the industrial and municipal loadings.
3. The nutrient and oxygen balance.
4. The circulation patterns and dispersion in the harbour.
5. Potential water quality problems such as PCB, mercury, oil and cadmium.

APPROACH TO MODELLING

Any model of the harbour is dependent on an understanding of the harbour processes such as mass exchange between the harbour and lake water, harbour circulation, variations and types of industrial and municipal waste discharges, existing dissolved oxygen and nutrient balances, etc., and measurements of these processes. The waste discharges can then be varied and/or relocated and the effects determined under various harbour conditions. It is suggested that several different types of models be developed simultaneously to provide the necessary answers. The different models are discussed subsequently with their limitations.

A reactor model is simply a mass balance technique in which one simply subtracts flows out of the harbour from wastes discharged to the harbour to determine what remains in the harbour. The remainder is then considered to be uniformly distributed throughout the harbour, e.g. constant concentration everywhere in the harbour. This model provides no information on what happens in the harbour such as the cause of annoxic conditions at certain locations. Nor does it identify water quality problem areas within the harbour. It is, however, useful for examining longer term trends as it averages conditions over a period of time.

A numerical model permits concentration contouring to be carried out in the harbour for different waste discharges, currents, dispersion patterns, outflows from the harbour, water level conditions, stratification and harbour geometry. While the development of this type of model is expensive, once developed it provides a valuable water management tool. It is possible to vary shoreline geometry, discharge volumes, concentrations and location, artificially induced circulation or destratification, receiving water physics or chemistry and determine the effects on the water quality. The model is transferrable to other areas like Toronto Harbour, Thunder Bay, etc. Such a model can also be developed in stages and refined with each application to a new location. It is important to realize that no capability of this type is available in the Ministry of the Environment and is a requirement for regional water management programs. In financial terms, the investment in the model development is small in comparison to capital works costs which may not significantly improve water quality in the harbour. This type of model is presently limited to two dimensions and limited in handling chemical and biological processes taking place in the harbour.

The historical water quality data available in the harbour provides a good basis to develop long term statistical trends and regions of the harbour which are showing water quality degradation. It is a valuable tool but is limited to predicting on the basis of existing conditions.

The complexity of the harbour indicates all these modelling approaches should be undertaken concurrently to achieve the required answers:

1. A statistical analyses of existing and new data to provide trend and variation information.

2. A reactor model assuming a homogeneous mixture and carrying out a material balance on various time scales.

3. A numerical model which will permit the effect of varying the shoreline geometry to be assessed as well as varying discharge volumes and locations.

4. A quantitative understanding of primary systems such as the nutrient (phosphorus and nitrogen) cycle and oxygen budget to provide guidelines for water quality management. The nutrient is important as phosphates will be removed from the municipal wastes as well as iron discharges from the industrial wastes. At the same time, turbidity has been reducing over the past few years. These factors may combine to produce a proliferation of algae blooms.

In addition to the modelling of the the above parameters, other water quality degradation sources must be identified and indicate what action is required to rectify these sources.

SURVEYS

Water Quality

Harbour

The seven station sampling grids established by the City of Hamilton, plus a station near the north shoreline, will be sampled every week for 4 or 5 months. Analysis of the samples will include the following:

1. Nutrients.
2. Chlorophyll.
3. DO.
4. Temperature.
5. Conductivity.
6. Chloride.
7. Hardness
8. Dissolved & Suspended Iron.
9. Bacteria
10. pH

11. Turbidity.

12. Secchi Disc.

13. Alkalinity.

14. Bathythermograph casts at each station.

Water samples will be collected at the surface and 1.5 m intervals to the 6 m depth and 3 m subsequently. Duplicate sampling and analyses will be done at three stations during the surveys to establish field sampling variations.

Once a month for three months, the survey will be expanded to 17 stations.

Surface water samples will be collected to determine oil content in a manner specified by Chemistry 11. Initially, one set of samples will be collected at stations 2, 3, 4, 5 and 7. Further sampling may be necessary depending on the results.

Recording water quality meters will be used to determine time variation of dissolved oxygen, temperature, conductivity, turbidity and pH near the Ottawa Street slip, offshore of Pier 16 (Stelco outfall) and the municipal treatment plant discharge. The meters will operate at each location for 10 days on half-hour sampling interval. During the meter operation one 24 hour sampling program of the principle industrial and municipal waste outfall concentrations and flows will be undertaken.

Two recording chemistry meters in conjunction with recording current meters will be operated near the surface and near the bottom in the ships' channel to determine mass transport out of the harbour. Some grab sampling will be done in the ships' channel to calibrate the recording meters. It is expected that this survey will be approximately 24 samples spread out over the period of the total study.

One of the major storm overflow sewers on the south shore will be monitored during a dry and wet period to determine loading to the harbour. If the loading is significant in comparison to other industrial and municipal outfalls, a program will be initiated to determine the loadings of all principle sewer outfalls.

BOTTOM SEDIMENTS

Bottom sediments will be sampled once during the study. Three bottom samples will be taken at each station 2, 3, 4, 5 and 7. The three samples will be collected with a bottom area of 7-13 m. These samples will be analyzed for mercury, cadmium, PCB, oil and kjeldahl nitrogen. Sampling procedures will be specified by Chemistry 11.

WATER LEVELS

The Hydrographic Service (Federal) has operating recording water level gauges at each end of the ships' channel and at the western end of the harbour. The existing gauges on the ships' channel lack the required precision for measuring water exchanges between the harbour and lake in the channel. C.C.I.W. will install and operate precise water level recorders in the channel by the end of May. C.C.I.W. will also measure velocity transects in the channel periodically during the summer. Records from all the gauges will be available to the Water Quality Branch. In addition, it is planned to co-ordinate water chemistry surveys in the channel with the velocity transect measurements.

WATER MOVEMENT

Drogues will be tracked during the 17 station sampling survey at stations 1, 2, 3, 4, 5, 7 and 8.

Three recording current meters will be operated at selected locations in the harbour for a period of six months after a preliminary drogue study has been carried out to determine if measurable currents exist.

DISPERSION

Three single impulse dye injection studies will be carried out during the 17 station survey to determine dispersion.

BIOLOGY

Bottom species and density will be determined at 17 stations, once in August, to determine whether changes have occurred since the 1964 survey. Approximately 34 samples will be collected.

SURVEY REQUIREMENTS

Analysis Estimates

Approximately 40 samples will be generated every week on the 8 station surveys every two weeks and 110 samples on the 17 station surveys three times during the 4-5 month survey. Fifteen bottom samples will be collected, 34 biological bottom samples will be collected for species identification and density.

Water Chemistry Surveys

A sampling vessel and crew are required for 40 survey days in the harbour.

Biological Surveys

Five survey days are required for a vessel and sampling crew. Laboratory time for species identification and desnity is approximately 8 man days.

Recording Instrumentation

The installation and operation of recording equipment and data analysis requires approximately 220 man days.

Modelling, Statistical Analysis and Report Writing

The services of a scientific programmer are required for approximately 9 months and a scientific staff member for approximately 2 months.

Dye Dispersion Studies

Approximately 40 man days are required for the dye dispersion runs and analysis of the data.

Instrumentation

Two recording chemistry and current meters are required on the ships' channel. As this is the only outlet to the harbour the models require that it be defined in detail over the period of study. It is recommended that the robot monitors from the Ottawa River be re-located on the ships' channel. Recording current meters would be available from existing inventories.

Two submersible chemistry and current meters are required at various locations adjacent to major industrial discharges. The chemistry meters are in the inventory but require up-dating while the current meters are available.

REFERENCES

ONTARIO WATER RESOURCES COMMISSION

1966 Biological Survey of Hamilton Bay and Adjacent Lake Ontario, 1964-65, M.G. Johnson.

1967 Detailed Survey South Shore of Hamilton Bay, December 19, 1967.

1967 City of Hamilton Water Pollution Survey of Sewer Outflows and Tributary Streams, San.Eng.

1972 Great Lakes Survey Data, 1969-1971.

1972 Industrial Waste Discharge Reports, 1971.

CITY OF HAMILTON

1958 A consolidated Report on Burlington Bay, D.H. Matheson.

1963 A Sanitary Survey Study of the Western End of Lake Ontario, 1961-63. D.H. Matheson.

1966 Municipal Laboratories Annual Report, D.H. Matheson.

1970 A Sanitary Survey of the Creeks Within the Hamilton Conservation Authority, D.H. Matheson.

1970 Municipal Laboratories Annual Report - Water Pollution Surveys, Section 3, D.H. Matheson.

1971 Municipal Laboratories Annual Report - Water Pollution Surveys, Section 3, D.H. Matheson.

CANADA CENTRE FOR INLAND WATERS - BURLINGTON

1972 Thermal Wedge in an Inlet into Lake Ontario, T.M. Dick and J. Marsalek.

APPENDIX 1

HAMILTON HARBOUR MODELLING STUDY

ESTIMATES OF COSTS
($000)

BRANCH

	Water Quality			Administrative Services			Laboratory			Total
	1972/73	1973/74	1974/75	1972/73	1973/74	1974/75	1972/73	1973/74	1974/75	
Complement	Nil	Nil	Nil	Nil	Nil	-	Nil	Nil	-	
Salaries and Wages										
- Regular	9.1	6.7	1.8	9.1	3.5	-	10.9	2.2	-	43.3
- Casual	3.9	-	-	-	-	-	9.9	2.2	-	16.0
Employee Benefits	1.0	0.7	0.2	0.9	0.4	-	1.2	0.2	-	4.6
Transportation & Communications	1.0	0.4	-	-	-	-	-	-	-	1.4
Services	15.8	3.2	1.0	19.0	7.1	-	-	-	-	46.1
Supplies and Equipment	18.7	-	-	-	-	-	-	-	-	18.7
TOTAL	49.5	11.0	3.0	29.0	11.0	-	22.0	4.6	-	130.1
Existing Budgetary Provision	15.8	11.0[1]	3.0[1]	29.0	11.0[1]	-	22.0	4.6[1]	-	96.4
Additional Funds Required	33.7	-	-	-	-	-	-	-	-	33.7

Remarks: The additional funds are required to measure the time variation of the exchange of harbour and Lake Ontario water and similar variations of the industrial and municipal waste discharges. Determination of these variables is considered essential in the model development.

(1) Budgetary provision will be made in the 1973/74 and the 1974/75 estimates at current policy level.

APPENDIX 1 (Cont.)

ESTIMATES OF COSTS - ADDITIONAL FUNDS REQUIRED

Ships' Channel Study

1. Installation and operation of two recording chemistry meters on shore.

- electric wiring	$ 900.00
- housing	160.00
- flooring	80.00
- insulation	96.00
- pumps	290.00
- water lines, insulation and hardware	100.00
- submerged tower	
- fabrication	500.00
- installation	400.00
- maintenance	400.00
- removal	400.00
- sundry items	70.00
- fan	30.00
- house maintenance	80.00
- spar buoys	70.00
- data translation	400.00
- equipment maintenance	400.00
	$4,376.00

2. Installation and operation of two recording current meters.

- submerged tower or buoy system	
- fabrication	500.00
- installation	400.00
- maintenance including divers	900.00
- removal	400.00
- spar buoys	70.00
- equipment maintenance	1,400.00
- data processing	2,400.00
	$6,070.00

Harbour Study

1. One recording submersible water quality station 14,000.00

Harbour Study (Cont.)

2. Operation of recording water quality meters near major outfalls.

- buoy support system	
- fabrication (2 systems)	$ 800.00
- installation and removal (3 times)	800.00
- spar buoys	70.00
- equipment maintenance	900.00
- data translation	320.00
- flow meter	400.00
	$3,290.00

3. Operation of Recording Current Meters in 3 locations.

- buoy support systems	
- fabrication (3)	1,500.00
- installation and removal	1,000.00
- spar buoys	105.00
- diver's special service	300.00
- equipment maintenance	1,120.00
- data processing	1,900.00
	$5,925.00

SUMMARY

Ships' channel study	$10,446.00
Harbour study	$ 9,215.00
Equipment acquisition	$14,000.00

APPENDIX 2

SURVEY RESPONSIBILITIES

Water Quality Branch

1. The following aspects of the survey will be carried out:

    1. Water quality sampling including bottom sediments.
    2. Biological sampling.
    3. Modelling and nutrient cycle.
    4. Current and dispersion measurements.
    5. Installation and operation of recording meters.
    6. Co-ordination of the study.

Laboratory Branch

This branch will be responsible for the analyses of all water and bottom samples.

Administration Branch

This branch will be responsible for providing scientific programming support for the modelling.

Industrial Wastes Branch

The following aspects of the survey will be carried out:

1. Projection of future industrial wastes loadings and land filling operations.
2. Determination of the time variation of major industrial discharges.

Municipal Laboratories, Hamilton

The following aspects of the survey will be carried out:

1. Time variation of waste discharges from the sewage plant and monitoring the variation of water quality at the water intake.

2. Oxygen budget in the harbour.

3. Storm sewer overflow outfall study.

4. Bacti analyses.

C.C.I.W.

C.C.I.W. will be responsible for the water level survey in the ships' channel and the water transport through the channel.

APPENDIX 3

SURVEY TIMETABLE

	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July
Task				1972						1973				
Water Quality Surveys	- - - -	- - - -	- - - -	- - - -										
Biology Survey			- - - -											
Industrial and Municipal Loadings		- - - -	- - - -											
Recording Meter Operations		- - - -	- - - -	- - - -	- - - -	- - - -	- - - -							
Statistical Analyses		- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -					
Model Development		- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	
Reports														
- preliminary							- - - -	- - - -						
- modelling														
- preliminary												- - - -	- - - -	
Data Processing			- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	

TABLE 1

HAMILTON HARBOUR

ANNUAL MEANS

			Cond. umhos/cm	Total P mg/l	Total N mg/l	NH_3 mg/l N	Chl mg/l
1.	Harbour side of ships' channel	1969	522(15)	0.076(15)	3.98(16)		
		1970	566(10)	0.060(10)	4.70(10)	6.9(13)	54.6
		1971	581 (7)	0.053(7)	6.45(7)	9.1(16)	60.0
2.	Lake side of ships' channel	1969	383(6)	0.041(6)	1.50(6)		
		1970	407(4)	0.044(4)	1.64(4)		
		1971	426(9)	0.047(9)	2.83(9)		
3.	Lake	1969	342(10)	0.03(9)	0.58(10)		
		1970	340(9)	0.027(9)	0.48(9)		
		1971	335(11)	0.023(9)	0.51(10)		

TABLE 2

HAMILTON RAW WATER

INTAKE ON LAKE

AMMONIA MEANS FOR

NOVEMBER TO APRIL

	percent over 0.10 ppm	percent over 0.50 ppm	max ppm	lake offshore max ppm
1962	38	0.3	0.8	
3	38	1.3	1.05	
4	43	0.8	1.30	
5	51	0.8	0.65	
6	35	1.2	1.60	
7	20	0.7	1.60	
8	19	0.2	0.98	
9	30	0.8	0.81	0.48
1970	28	0.8	1.30	0.22
1	32	0.9	1.02	0.38

TABLE 3

STATISTICAL TESTS

ANALYSIS OF VARIANCE

Chlorides

Year	Number of Surveys	Difference between Stations	Results
1970	13	1,6 & 5	NS @ 0.05
1971	14		$F_{2,26} = 10.56 > F_{0.03} = 3.37$
1970	12	2,6 & 7	NS @ 0.05
1971	14		NS @ 0.05

Matched Pairs t Test

Between	TPO_4	Cond.
A1 & A 22	$t_3 = 3.39 > t_{0.025} = 3.18$	$t_3 = 5.01 > t_{0.02} = 4.54$
A22 & A1030	$t_5 = 5.52 > t_{0.01} = 4.03$	NS
A22 & A140	$t_6 = 8.98 > t_{0.01} = 3.71$	$t_6 = 3.83 > t_{0.01} = 3.71$

TABLE 4

PCB DATA

25 NOVEMBER 1971

Near #7	2.5 ppm
Near #2	0.4 ppm
Ottawa Station Slip	20.0 ppm
Pier 21 (Kenilworth Station)	23.0 ppm
Hamilton S.T.P. Outfall	46.0 ppm
North Shore	0.1 ppm.

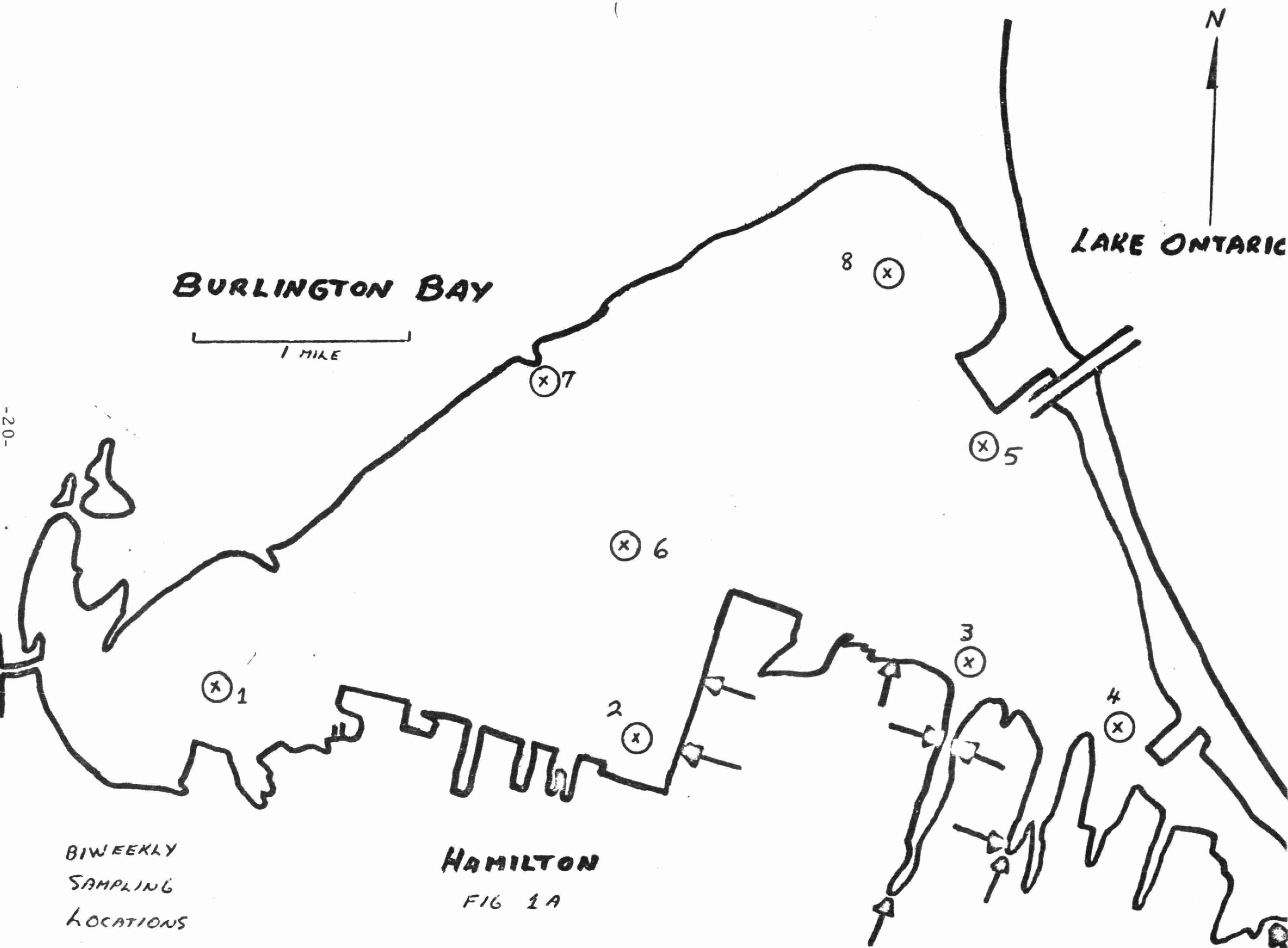
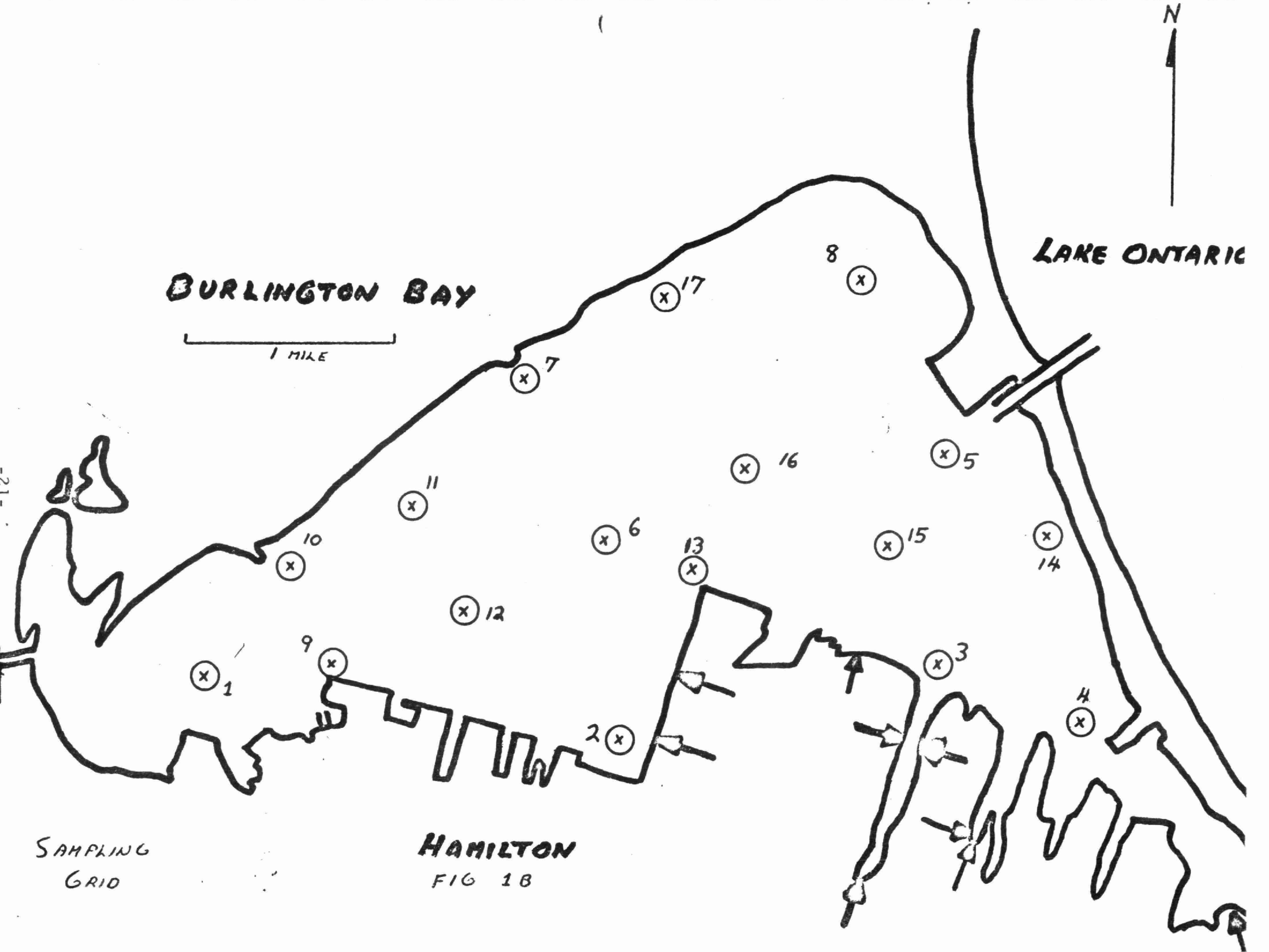


FIG 1A

BIWEEKLY SAMPLING LOCATIONS



SAMPLING GRID

FIG 1B

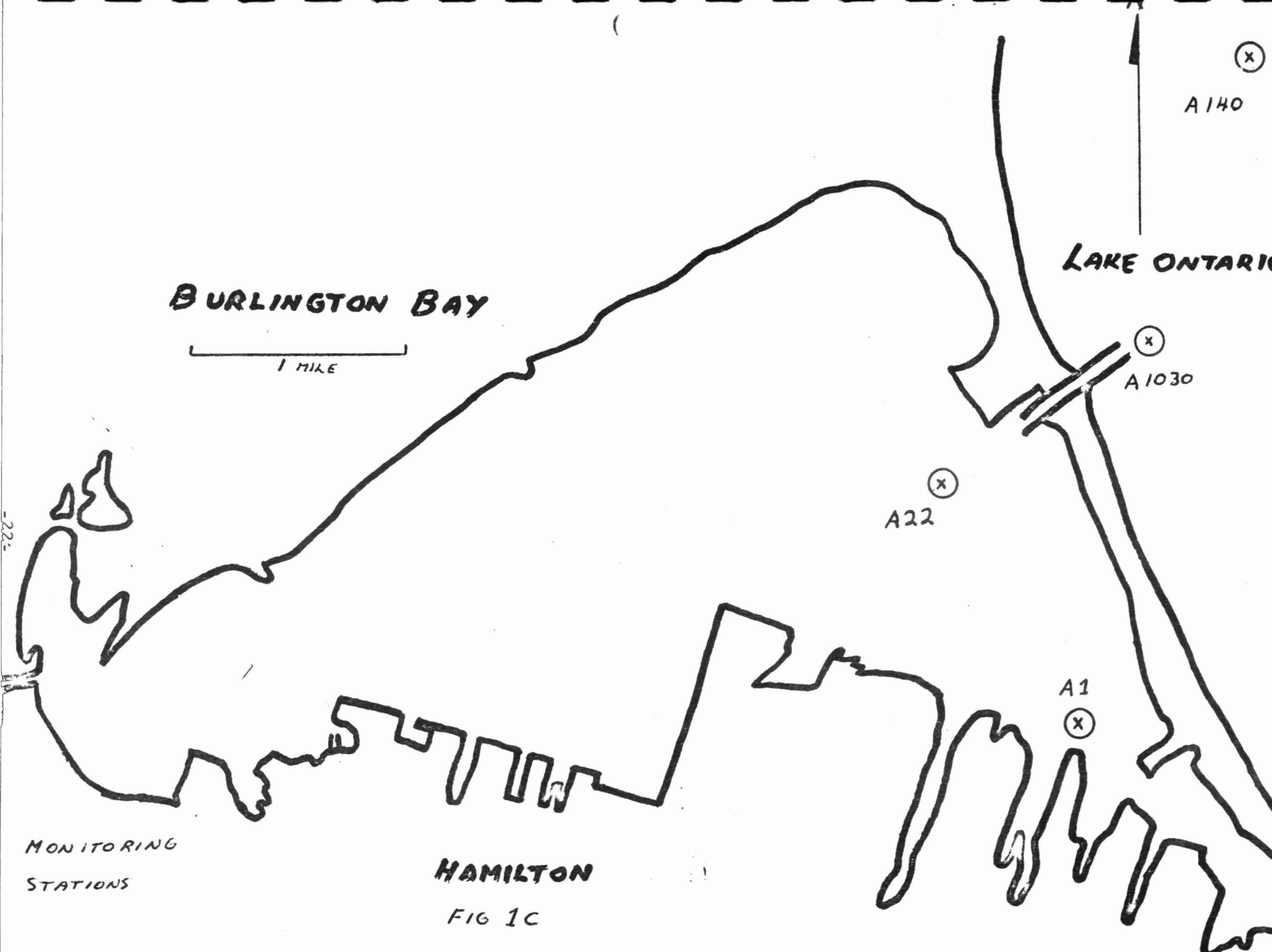

BURLINGTON BAY
1 MILE
LAKE ONTARIO
A140
A1030
A22
A1
MONITORING STATIONS
HAMILTON

FIG 1C

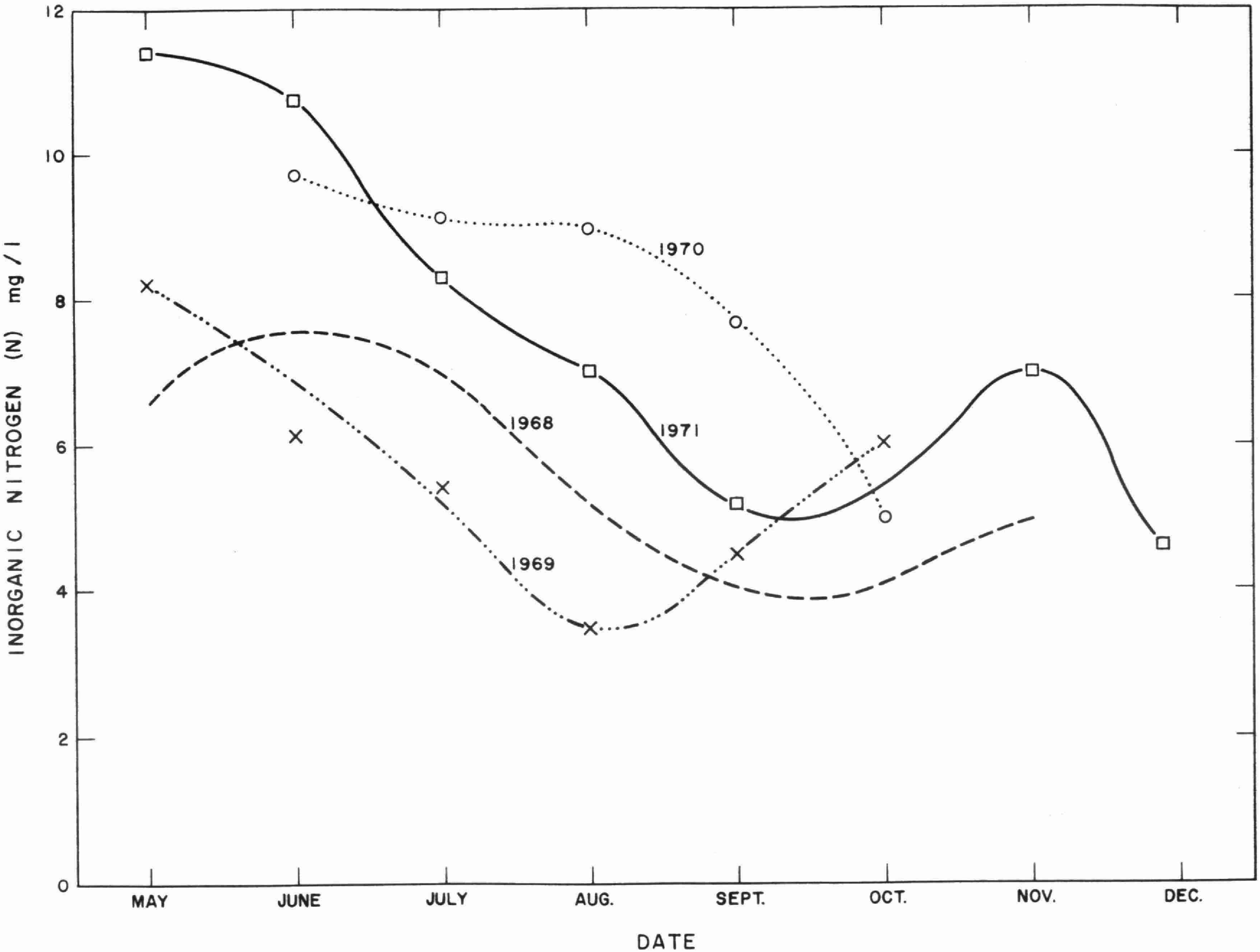


FIGURE 2 - INORGANIC NITROGEN IN HAMILTON HARBOUR